Idaho National Engineering and Environmental Laboratory

Fate and Environmental Impacts of Discharged CBM Produced Water¾ A Tracer Field-Demonstration Study in the Powder River Basin

Idaho National Engineering and Environmental Laboratory

Dr. Jenn-Tai Liang

Collaborators:

DOI-BLM, WDEQ

Industry Sponsors:

Marathon Oil, Nance Petroleum

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Presentation Outline

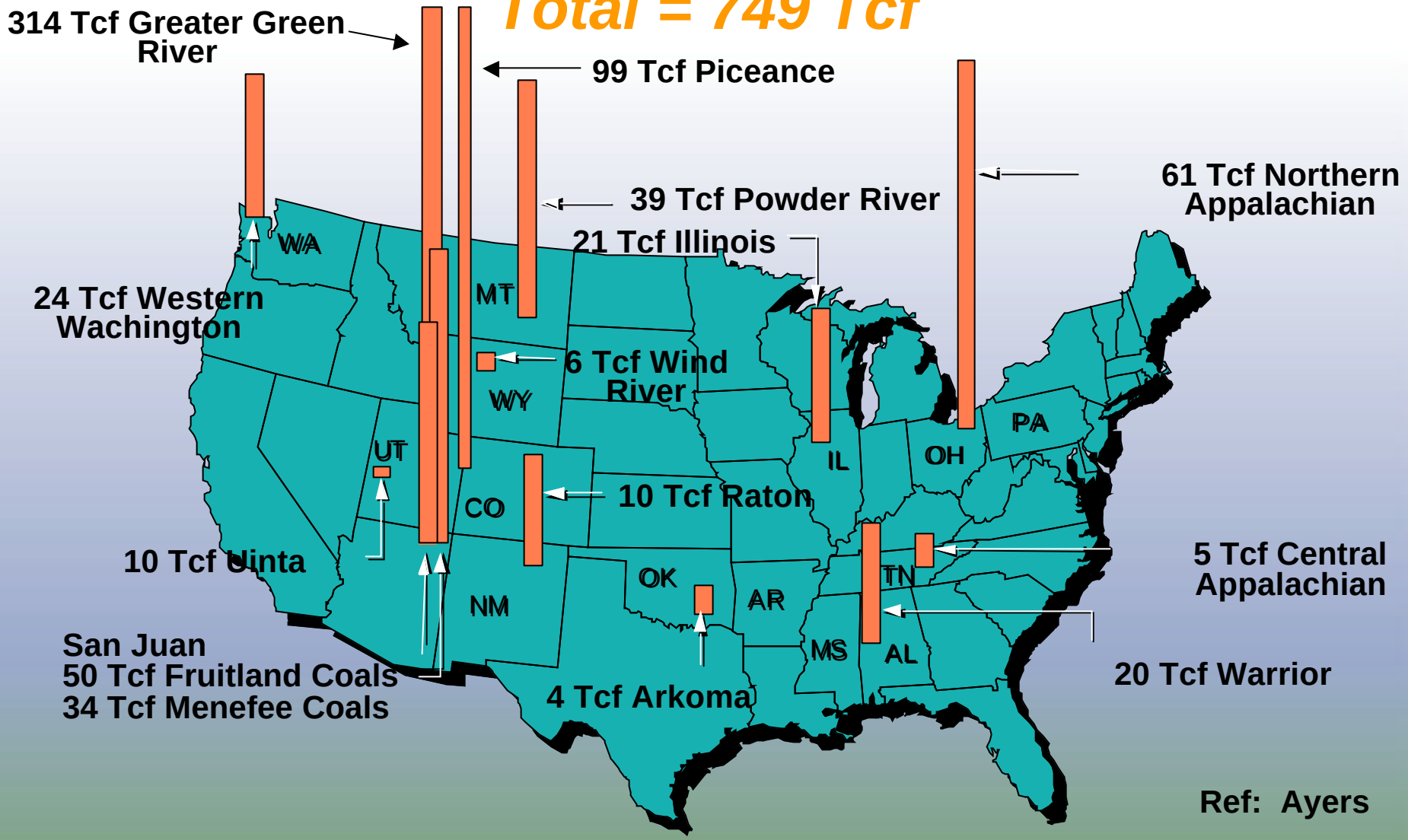
- Application & Benefits to Industry
- Background Information
- Statement of Problem
- Project Objectives
- Research Approach
- Project Deliverables

Application & Benefits to Industry

- The proposed research will provide a useful tool that both operators and regulatory agencies can use to track the surface discharged CBM produced water and understand its impact on the environment.
- The tracers identified in this study can be used to resolve disputes and identify the source of observed contamination.
- The model and methodology developed in this study can be expanded in the future to establish a risk-based protocol for basin-wide risk assessment of infiltration ponds in the Power River Basin and other CBM producing areas in the US.

U.S. Coalbed Methane Resources

Total = 749 Tcf



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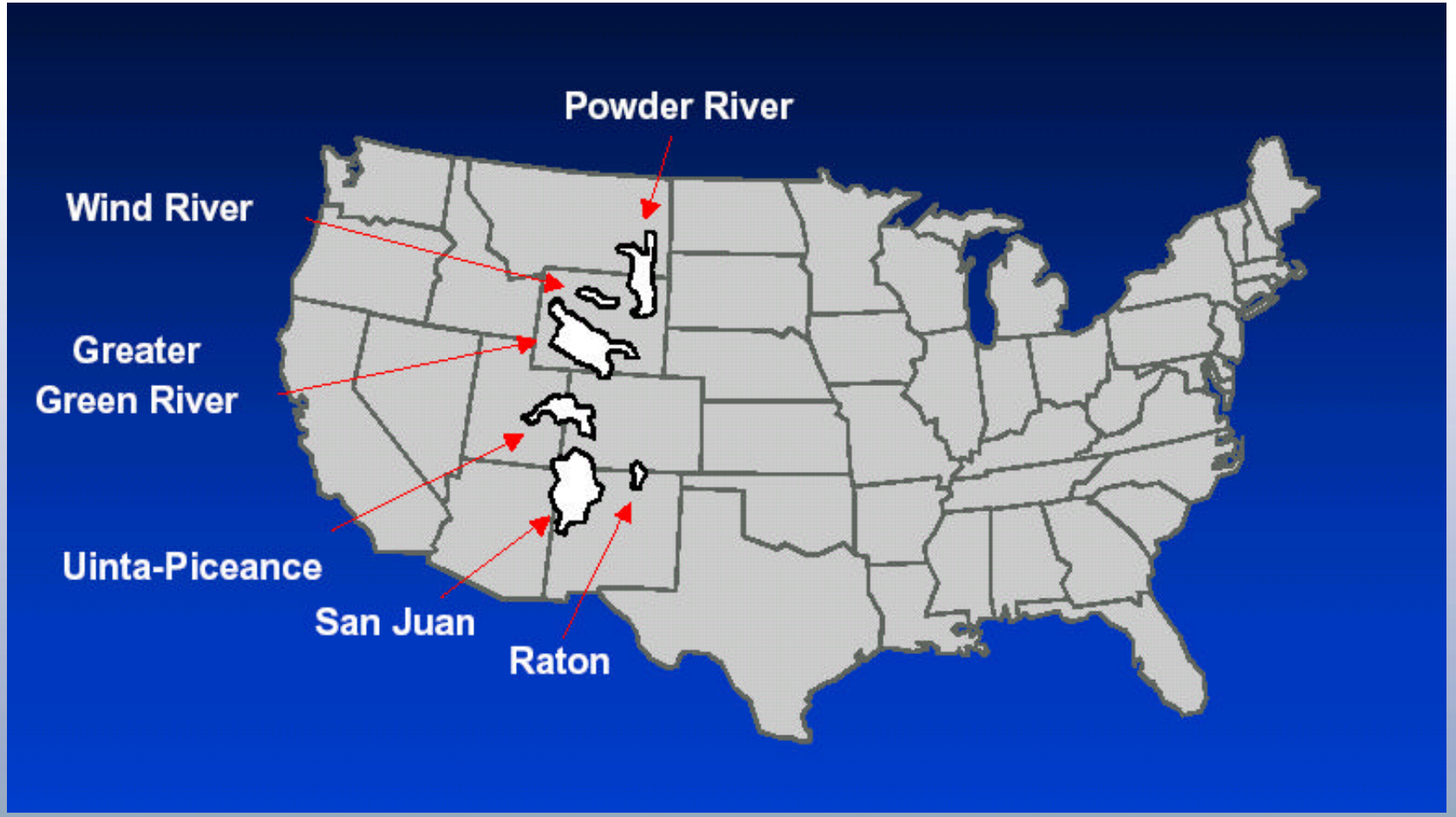
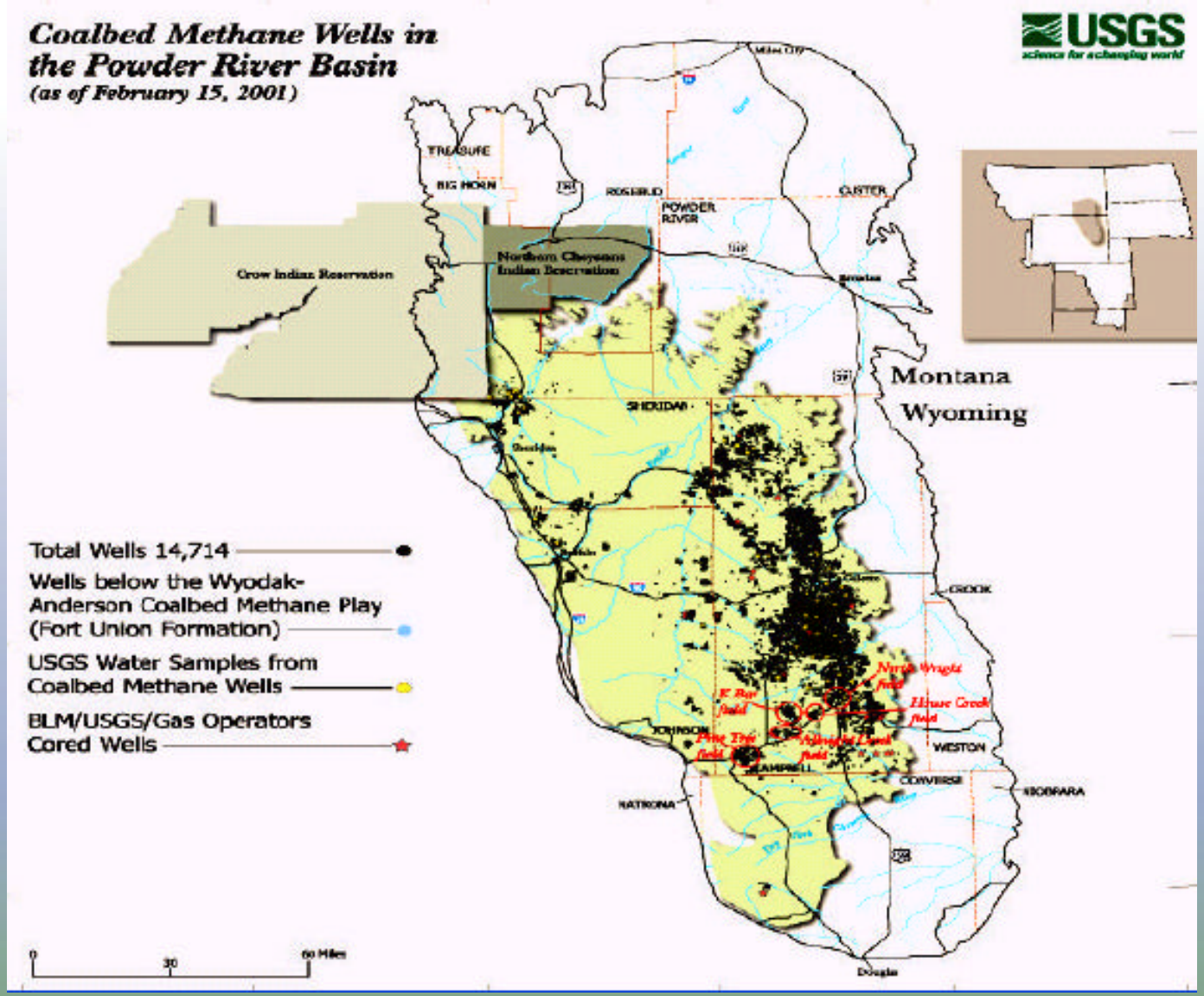

Powder River
Wind River
Greater
Green River
Uinta-Piceance
San Juan
Raton

CBM Permitted Wells in the Powder River Basin



CBM Development in the Powder River Basin

- CBM development progressed rapidly from the shallow eastern part of the CBM play westward.
- Well depths range from 100 feet to 2100 feet with an average depth of 767 feet.
- Well spacing is generally 80 acres per well.
- Individual coalbed thicknesses vary widely but average about 63 feet.
- Almost all the CBM production is from the Wyoming portion of the Powder River Basin. Currently, Wyoming is the most active natural gas play in the country.

CBM Production in the Powder River Basin

- Currently more than 10,000 active CBM wells in the area, expected to increase to 70,000 wells in the next 20 years.
- 250 million Mcf produced gas in 2001.
- 513 million barrels of produced water in 2001.
- 1.4 trillion gallons of produced water over the next 20 years.
- Up to 4,000 infiltration ponds needed to handle the produced water.

Powder River Basin CBM Produced Water Characteristics *(Source: USGS, 2000)*

Parameter	Minimum Value (mg/l)	Maximum Value (mg/l)	Mean Value (mg/l)
TDS	270	2010	862
Sodium	110	800	305
Calcium	5.9	200	36
Magnesium	1.6	46	16
SAR	5.7	32	11.7
Iron	0.02	15.4	0.8
Barium	0.1	8	0.6
Chloride	3	119	13
Sulfate	0.01	17	2.4

Potential Environmental Impacts

- Ground water contamination and/or drawdown
- Alternation of stream morphology and sediment generation
- Surface water and riparian zone alternation
- Local environment alternation

Options for Managing CBM Produced Water

- Direct surface discharge with treatment
- Direct surface discharge with treatment for beneficial reuse
- Discharge via ponding
- Discharge via reinjection

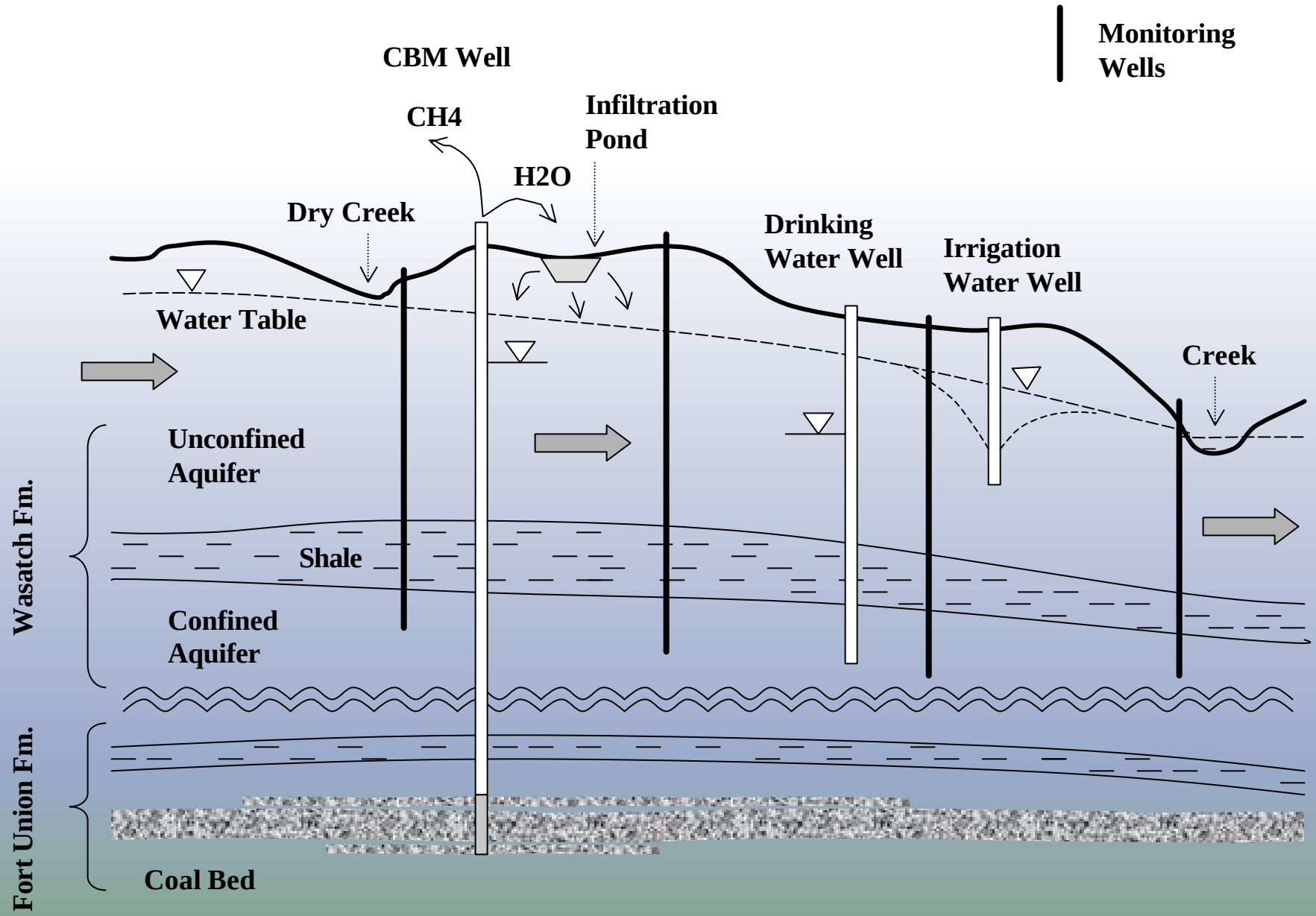
CBM Produced Water Management in Powder River Basin

- Direct surface discharge not allowed
- CBM produced water stored in unlined infiltration and/or evaporation ponds
- High evaporation and infiltration rates reduce size of the ponds
- Ponds also used for livestock watering

Infiltration Pond in the Powder River Basin

Statement of Problem

- To date, little information is available concerning the potential environmental impacts of discharged CBM produced water in the Powder River Basin.
- Wyoming DEQ has been sued over the potential for CBM produced water stored in infiltration ponds to contaminate shallow alluvial aquifers.
- There is a critical need to understand the fate and environmental impacts of discharged CBM produced water.


Monitoring Wells
CBM Well
CH4
Infiltration Pond
H2O
Dry Creek
Drinking Water Well
Irrigation Water Well
Water Table
Creek
Unconfined Aquifer
Wasatch Fm.
Shale
Confined Aquifer
Fort Union Fm.
Coal Bed

Project Objectives

- Identify effective and environmental friendly tracers to track and understand the environmental impacts of discharged CBM produced water.
- Model and predict the fate and underground transport of the discharged produced water.
- Verify and calibrate the model via actual field demonstration.
- The research will be performed in the context of an actual field demonstration.

Research Approach

Task 1. Identify Effective & Environmental Friendly Tracers (INEEL, BLM)

- As possible natural tracers, isotopic and chemical compositions of CBM produced water (water fingerprints) from different producing formation and locations near the field-demonstration sites will be analyzed and compared with those of water from shallow aquifers and the local discharge area.
- As in-kind contribution, BLM Buffalo Field Office in Wyoming will collect and analyze water samples.

Research Approach

Task 1 (Cont'd). Identify Effective & Environmental Friendly Tracers (INEEL, BLM)

- Applicability of environmentally safe and chemically inert artificial tracers (e.g., bromide, xenon, and krypton, …, etc.) will also be also examined.
- They will be used in the field-demonstration tests to verify and calibrate the predictive models developed in Task 2.

Research Approach

Task 1 (Cont'd). Identify Effective & Environmental Friendly Tracers (INEEL, BLM)

- Feasibility of using encoded synthetic DNA molecules to track CBM produced water from multiple sources will be studied.
- The synthetic DNA molecules (~10 nm) are environmentally safe and can be transported easily through the subsurface.
- With this novel technology, every infiltration pond could be tagged to carry its own unique DNA fingerprint.

Research Approach

Task 2: Modeling and Simulation of the Fate and Transport of Tracers and Infiltration Water

- Develop geologic and hydrologic conceptual models for selected field-demonstration sites.
- Develop the corresponding numerical models and Initial-boundary conditions.
- Perform full-scale simulations to predict the fate and transport of tracers and infiltration water.
- Refine the geological/simulation models by history matching the monitored field data.

Research Approach

Task 2 (Cont'd): Modeling and Simulation of the Fate and Transport of Tracers and Infiltration Water

- Study the feasibility of establishing a risk-based protocol using Monte Carlo simulation in conjunction with the distributions of geologic properties for basin-wide risk assessment of infiltration ponds in the Power River Basin.

Research Approach

Task 3. Field Demonstration (INEEL, BLM, WDEQ, Marathon Oil, Nance Petroleum)

- Suitable demonstration candidate sites will be selected during the first three months of the project cycle.
- Two demonstration sites will be selected, one with a known high conductivity path between the infiltration pond and the discharge areas; the other one with no known high conductivity path.
- Shallow monitoring wells will be drilled near the selected infiltration ponds to provide tracer transient time for the modeling study in Task 2.

Project Deliverables

- A useful tool that both operators and regulatory agencies can use to track the surface discharged CBM produced water and understand its impact on the environment.
- The tracers identified in this study can be used to resolve disputes and identify the source of observed contamination.
- The model and methodology developed in this study can be expanded in the future to establish a risk-based protocol for basin-wide risk assessment of infiltration ponds in the Power River Basin and other CBM producing areas in the US.

DETAILED BUDGET

Task	FY 2003	FY 2004	FY 2005	Total Task Budget
1. Selection of most effective and economic natural tracers and water labeling techniques				
• Labor	$130K	$130K	--	
• M&S (includes travel)	$30K	$30K	--	**$320K**
2. **Modeling and Simulation of the fate and transport of Tracers and infiltration water**				
• Labor	$105K	$130K	$105K	
• M&S (includes travel)	$10K	$10K	$10K	**$370K**
3. **Field Demonstration**				
• Labor	$15K	--	$135K	
• M&S (includes travel)	$10K	--	$50K	**$210K**
INEEL Annual Budget	$300K	$300K	$300K	
DOE Share	**$300K**	**$300K**	**$300K**	**$900K**
BLM (in-kind)*	$60K	$60K	$60K	**$180K**
Industry Cost Share – Marathon Oil (20%)	$60K	$60K	$60K	**$180K**
Industry Cost Share – Nance Petroleum (20%)	$60K	$60K	$60K	**$180K**
Total Budget	**$480K**	**$480K**	**$480K**	**$1440K**

***In-kind contribution for water sampling and analyses, site selection, tracer monitoring.

Backup Slides

Geologic and Hydrologic Conceptual Model

- At least one core sampling well/hole will be drilled at each testing site to obtain the representative soil/rock profile.
- The sampled soil/rock profile will be correlated with logs from nearby CBM wells and other geologic models.
- The historic data of impounded water and the fluctuation of local water table will be collected from any available sources.
- The model setting will be site-specific. It will consist of a single (or a few) infiltration pond(s) and its surrounding area laterally to nearby discharge streams/sites, and vertically from surface to the top of the Wasatch formation.

Numerical Models and Their Initial and Boundary Conditions

- According to flow regimes, 2-D or 3-D numerical models will be constructed for a subsurface region that consists of a vadose zone and a saturated zone.
- Numerical grids will be designed to distinguish the interbedded sediments that comprise the subsurface are characterized by complex structure in terms both of preferential flow paths and of layers that contrast in thickness, permeability, porosity and other properties.
- Initial and boundary conditions will be determined according to the historic and monitored measurements.

Simulating the Fate and Transport of Infiltration Water

- Amount of perched water in vadose zone.
- Time frame and rate of infiltration water reaching the saturated zone.
- Amount of infiltration water discharging into nearby ephemeral or perennial streams, i.e. the water returned to surface.
- Vertical communication between the shallow aquifer and the underlying Wasatch formation.
- Infiltration rate from surface infiltration ponds.
- Inflow from up-gradient and outflow to down-gradient in saturated zone.
- Soil salinization resulting from mixing the CBM-produced water in unconfined aquifer.

Model Validation via Tracer Monitoring

- The observed data from tracer monitoring will be used to verify and fine tune the simulation model to comply with the geologic reality.
- Special attention will give to any possible preferential flow paths that can transport water horizontally to adjacent regions or vertically to the underlying Wasatch formation far sooner than might be predicted based on average medium properties.

Probability-Based Monte Carlo Simulation